25 Astronomy and cosmology

25.1 Standard candles

Candidates should be able to:	
1	understand the term luminosity as the total power of radiation emitted by a star
2	recall and use the inverse square law for radiant flux intensity F in terms of the luminosity L of the source $F = L/(4\pi d^2)$
3	understand that an object of known luminosity is called a standard candle
4	understand the use of standard candles to determine distances to galaxies

- Luminosity L is defined as **the total power output of radiation emitted by a star**.
- It is measured in **Watts**
- The observed amount of intensity F is **the observed amount of intensity, or the radiant power transmitted normally through a surface per unit of area, of radiation measured on defined as Earth.**
- Light leaving a star can be assumed to be a uniformly spread out like a spherical shell.
- Hence, the inverse square law of flux can therefore be calculated using

$$F = \frac{L}{4\pi d^2}$$

  Here L is the luminosity of the source (watts), d is the distance between the star and Earth (m).
- F is measured in Wm^{-2}
- **Standard candle** is defined as **an astronomical object which has a known luminosity due to a characteristic quality possessed by that class of object**.
- By knowing luminosity of a source, the distance can be estimated based on how bright it appears on Earth.

25.2 Stellar radii

Candidates should be able to:	
1	recall and use Wien's displacement law $\lambda_{max} \propto 1/T$ to estimate the peak surface temperature of a star
2	use the Stefan–Boltzmann law $L = 4\pi\sigma r^2 T^4$
3	use Wien's displacement law and the Stefan–Boltzmann law to estimate the radius of a star

- **Wien's Law** states that **the black body radiation curve for different temperatures peaks at a wavelength λ_{max} which is inversely proportional to the temperature (T)**

$$\lambda max \propto 1/ T$$

- This equation tells us that the higher the temperature of a body the shorter the wavelength.
- The full equation for Wien's Law is given by

$$\lambda_{nax}T = 2 \cdot 9 \times 10^{-3}$$

- Stefan-Boltzmann Law states that the total energy emitted by a black body per unit area per second is proportional to the fourth power of the absolute temperature of the body.
- This can be expressed as

$$L = 4\Pi r^2 \sigma T^4$$

  Here r is the radius of the star (meters), **σ is Stefan-Boltzmann constant (5.67×10^{-8} $Wm^{-2}K^{-4}$) and T is the surface temperature of the start (Kelvin).**
- The radius of a star can be estimated by combining Wien's displacement law and Stefan-Boltzmann law
- First use Wien's displacement law to find the surface temperature of the star.
- Using inverse square law of flux equation to find luminosity of the star
- Finally, using SB law to find the stellar radius of the star.

25.3 Hubble's law and the Big Bang theory

Candidates should be able to:

1 understand that the lines in the emission and absorption spectra from distant objects show an increase in wavelength from their known values

2 use $\Delta\lambda/\lambda \approx \Delta f/f \approx v/c$ for the redshift of electromagnetic radiation from a source moving relative to an observer

3 explain why redshift leads to the idea that the Universe is expanding

4 recall and use Hubble's law $v \approx H_0 d$ and explain how this leads to the Big Bang theory (candidates will only be required to use SI units)

- One of the ways astronomers investigate objects in space is by looking at the emission and absorption spectra of stars.
- Elements in stars absorb some of the emitted wavelengths.
- These characteristic lines are present when the spectrum is analysed.

- Compared to the sun, spectral lines from stars in distant galaxies appear to be shifted slightly.
- The lines show an increase in wavelength
- The lines are moved or shifted towards the red end of the spectrum.
- This phenomenon is called redshift.
- Due to the Doppler effect on light, redshift on the spectral lines occurs when an object is moving away from the earth and blueshift when it is moving towards.
- Doppler shift can be calculated using

$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta f}{f} = \frac{v}{C}$$

  Here $\Delta\lambda$ is the shift in wavelength (m), λ is the wavelength emitted from the source (m), Δf shift in frequency (Hz), f is the frequency emitted from the source (Hz), v is the speed of recession (ms^{-1}) and c is the speed of light (ms^{-1}).
- Due to the Doppler redshift, astronomers believe that the galaxies are expanding.
- The more red-shifted the light from a galaxy is, the faster the galaxy is moving away from earth.
- **Hubble's Law** states that **the recession speed of galaxies moving away from Earth is proportional to their distance from the Earth**

$$V = H_0 d$$

- Here v is the galaxy's recessional velocity (ms^{-1}), d is the distance between the galaxy and earth (m) and H_0 is Hubble's constant (s^{-1}).
- The Big Bang theory states that universe expanded from an initial state or point of extremely high density and high temperature which then began to expand very quickly.
- Evidence for this theory comes from redshifted galaxies and the ever expanding universe.
- Data from Hubble's Law can be extrapolated back to the point that the universe started expanding i.e., the beginning.